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Description
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SOLID-STATE IMAGING DEVICE, MANUFACTURING METHOD FOR SOLID-STATE IMAGING DEVICE, AND CAMERA USING THE SAME

Related Application

This application is a national phase of PCT/JP2004/011400 filed on August 2, 2004, which claims priority from Japanese Application No. 2003-285254 which was filed on August 1, 2003, the disclosures of which Applications are incorporated by reference herein. The benefit of the filing and priority dates of the International and Japanese Applications is respectfully requested.

Technical Field

The present invention relates to a solid-state imaging device, a manufacturing method for a solid-state imaging device, and a camera using the same, and in particular to a technique for achieving a color solid-state imaging device of improved performance and smaller size.

Background Art

In solid-state imaging devices, light receiving elements corresponding to red (R), green (G), and blue (B) are arranged, for example, in a Bayer array. FIG. 1 is a schematic cross-sectional view illustrating a construction of a conventional solid-state imaging device. As shown in FIG.1, a solid-state imaging device 1 includes an N-type semi-conductor layer 101, a P-type semiconductor layer 102, light receiving elements 103R, 103G, 103B, an insulation layer 104, light shielding films 105, color filter 106R, 106G, and 106B, and collective lenses 107.

The P-type semiconductor layer 102 is formed on the N-type semiconductor layer 101. The light-receiving elements 103R, 103G, and 103B are buried in the P-type semiconductor layer 102, so as to be in contact with the insulation layer 104. Here, the light-receiving elements 103R, 103G, and 103B are separated from one another, with separation parts of the P-type semiconductor layer 102 therebetween. The light shielding films 105 are buried in the insulation layer 104, so as to be positioned above the separation parts of the P-type semiconductor layer 102.

The color filters 106R, 106G, and 106B are of the type that contains fine pigment particles, and have a thickness of approximately 1.5 μm to 2.0 μm. The pigment particles have a diameter of approximately 0.1 μm.

The color filter 106R is provided on the insulation layer 104 so as to oppose the light-receiving element 103R. Similarly, the color filter sections 106G and 106B are provided on the insulation layer 104 so as to oppose the light-receiving elements 103G and 103B respectively. One of the collective lenses 107 is provided on each of the color filter 106R, 106G, and 106B.

Of the light that has passed through the corresponding collective lens 107, the color filter 106G transmits only green light, and the green light is collected on the light-receiving element 103G. The light shielding films 105 prevent the green light, which has been transmitted through the color filter 106G, from entering the light-receiving elements 103R and 103B. Here, the light-receiving elements 103R, 103G, and 103B convert luminance of received light into an electric charge by photoelectric conversion, and store therein

the electric charge.

Such a solid-state imaging device appears, for example, in Japanese Laid-open Patent Application No. H05-6986, and in "*Kotaisatsuzousoshi no kiso*" (The basics of solid-state imaging devices), *Nihon Rikou Shuppannkai* (Japan Science and Technology Publishing), by Andoh and Komobuchi, the Institute of Image, Information and Television Engineers, December 1999, p.183-188.

Disclosure of the Invention

With light entering a solid-state imaging device from various directions, there is a risk of the light that enters obliquely (hereinafter oblique light) being received by a light-receiving element other than the intended light-receiving element, thereby degrading color separation, decreasing resolution and wavelength sensitivity, and increasing noise.

Moreover, in order to increase the resolution of a solid-state imaging device its pixels have to be reduced in size. However, there is a limit as to how far the size of the pigment particles can be reduced, beyond which a loss of sensitivity and color uniformity inevitably occurs.

In order to solve these problems the present invention is a solid-state imaging device including: a plurality of light-receiving units two-dimensionally arrayed in a semiconductor substrate; a filter unit operable to transmit incident light of selected wavelengths to the plurality of light receiving units; and a light shielding unit operable to shield incident light, the light shielding unit having a plurality of apertures, each aperture opposing a

corresponding light receiving unit, wherein on a path of incident light from the light shielding unit to the plurality of light-receiving units, the filter unit is disposed between the light shielding unit and the plurality of light-receiving units.

With this construction, oblique light can be shielded such that it does not enter the filter unit, and i to reduce color mixing can therefore be reduced.

Here, the solid-state imaging device may further include a condensing unit operable to condense incident light on the corresponding light-receiving unit disposed in each of the plurality of apertures in the shielding unit.

With this construction, the condenser unit concentrates light on the appropriate light-receiving unit, and color mixing can therefore be reduced.

Further, the filter unit may be composed of an inorganic material. According to this construction, the filter unit can be manufactured in a series of semi-conductor substrate manufacturing processes, and it is therefore possible to improve the yield of solid-state imaging devices and reduce manufacturing costs.

The filter unit may have a multilayer film structure. With this construction, the thickness of the filter unit can be reduced, contributing to a reduction in the overall size of the solid-state imaging device.

The filter unit may be composed of photonic crystal. Further, the present invention is a solid-state imaging device including: a plurality of light-receiving units two-dimensionally arrayed in a semiconductor substrate; and a filter unit operable to transmit

light of selected wavelengths to the plurality of light receiving units, wherein the filter unit is composed of photonic crystal. According to this construction, the filter unit concentrates oblique light on the appropriate receiving unit, and it is therefore possible to prevent color mixing.

Further the present invention is a camera including the solid-state imaging device having a plurality of light-receiving units two-dimensionally arrayed in a semiconductor substrate; a filter unit operable to transmit incident light of selected wavelengths to the plurality of light receiving units; and a light shielding unit operable to shield incident light, the light shielding unit having a plurality of apertures, each aperture opposing a corresponding light receiving unit, wherein on a path of incident light from the light shielding unit to the plurality of light-receiving units, the filter unit is disposed between the light shielding unit and the plurality of light-receiving units.

Further, the present invention is a camera including a solid-state imaging device having: a plurality of light-receiving units two-dimensionally arrayed in a semiconductor substrate; and a filter unit operable to transmit light of selected wavelengths to the plurality of light receiving units, wherein the filter unit is composed of photonic crystal. According to this construction, it is possible to provide a camera capable of preventing color mixing and of taking high quality images.

Brief Description of the Drawings

FIG. 1 is a cross-sectional view illustrating a construction of a solid-state imaging device;

FIG. 2 is a plan view illustrating a construction of a solid-state imaging device of a first embodiment of the present invention;

FIG.3 is a cross-sectional view illustrating a construction of a solid-state imaging device of the first embodiment of the present invention;

FIG. 4 is a cross-sectional view illustrating a construction of a solid-state imaging device of a third embodiment of the present invention.

Best Mode for Carrying Out the Invention

The following describes, with reference to the figures, a solid-state imaging device, a manufacturing method for a solid-state imaging device, and a camera, which relate the present invention.

(1) First Embodiment

FIG. 2 is a plan view illustrating the construction of the solid-state imaging device of the first embodiment. As shown in FIG. 2, in the solid-state imaging device of the first embodiment, unit pixels (shaded parts), which are light-receiving units, are two-dimensionally arranged. A vertical shift register selects a row, and a horizontal shift register selects a signal in a pixel in the selected row. In this way, a color signal corresponding to each pixel is output through an output amplifier (not illustrated). A driving circuit causes the vertical shift register, horizontal shift register, and output amplifier to operate.

FIG. 3 is a cross-sectional view illustrating the construction of a solid-state imaging device 2 of the first embodiment of the present invention. Specifically, it shows three neighboring pixels

in cross-section. As shown in FIG. 3, the solid-state imaging device 2 includes an N-type semiconductor substrate 201, a P-type semiconductor substrate 202, light-receiving elements 203R, 203G, and 203B, insulation layers 204 and 206, color filter 205R, 205G and 205B, a light shielding film 207, and micro lenses 208.

The P-type semi-conductor substrate 202 is formed on the N-type semiconductor substrate 201. The light receiving elements 203R, 203G, 203B are photodiodes (photoelectric converting elements) composed of a P-type semi-conductor substrate layer infused with N-type impurities, and are in contact with the light-transmitting insulating layer 204. The light-receiving elements 203R, 203G, and 203B are separated from one another by corresponding parts of the P-type semiconductor substrate, each of which acts as a separation part between two neighboring elements. The color filter 205R, 205G and 205B is formed on the insulating layer 204.

Each section of the color filter 205R, 205G, and 205B exclusively passes R, G, or B, accordingly, where R, G, and B denote the primary colors of light. The color filter 205R, 205G, and 205B is of the type containing fine pigment particles composed of an inorganic material, and its sections are arranged in a Bayer array or complementary color mosaic.

A light-transmitting insulating layer 206 is formed on the color filter 205R, 205G, and 205B. The micro lenses 208 are disposed in one-to-one correspondence with the light-receiving elements, and are separated from one another by the light shielding film 207. Light incident upon the light shielding film is reflected. On the other hand, light incident on any of the micro lenses 208 is concentrated

on the corresponding light-receiving element 203R, 203G, or 203B.

With this construction, it is possible to reduce, in comparison to conventional techniques, the distance between the color filter and the receiving element, and therefore to reduce the likelihood of oblique light entering the receiving elements. For instance, if the width of one of the receiving elements 203R, 203G, or 203B is 3 µm, it is possible to reduce color mixing by approximately 80% in comparison to conventional techniques. Further, the solid-state imaging device 2 can be entirely manufactured using semi-conductor related processes, and can therefore be manufactured simply and at low cost.

[2] Second Embodiment

The following describes the second embodiment of the present invention. The solid-state imaging device of the second embodiment largely resembles that of the first embodiment, but differs in that the color filter is composed of photonic crystals.

Photonic crystals are microstructures in which materials of differing permittivities and refraction indices, such as the semiconductor substrate and air for instance, are arranged in alternating layers, such that two contacting layers have a thickness of the order of the wavelength of light. Besides functioning as a filter that transmits only light of a specific wavelength, photonic crystals have the property of conducting incident light in a specific direction. Photonic crystals that do not transmit light of the particular range of wavelengths corresponding to the width of their band gap, namely photonic crystals having a photonic band gap are introduced in the following document:

NODA Susumu, MORIMOTO Shigeo, "*Naimen hetero fotonikku kesshou ni yoru hikari nanodebaisu no jitsugen*" *Kagaku gijutsu shinkou danhou dai 323 go* (Realizing optical nano-devices using in-plane hetero-photonic crystals, Japanese Science and Technology Corporation Journal, Issue 323).

If such photonic crystals are used as the color filter, in addition being able to selectively transmit the primary colors of light, the color filter can adjust the direction of light propagation, and therefore further prevent color mixing.

[3] Third Embodiment

The following describes the third embodiment of the present invention. The solid-state imaging device of the third embodiment largely resembles that of the second embodiment, but differs in the positioning of the shielding film.

FIG. 4 is a cross-sectional view illustrating the construction of a solid-state imaging device of the third embodiment. As shown in FIG. 4, the solid-state imaging device 3 includes an N-type semiconductor substrate 301, a P-type semiconductor substrate 302, light-receiving elements 303R, 303G, and 303B, insulation layers 304 and 307, a light shielding film 305, color filter 306R, 306G and 306B, and micro lenses 308.

The solid-state imaging device 3 is structured such that the P-type semiconductor substrate 302, the light-receiving elements 303R, 303G, and 303B, the light-transmitting insulating layer 304, the light shielding film 305, the color filter 306R, 306G, 306B, and the micro lenses 308 form respective layers on the N-type semiconductor substrate 301. The color filter 306R, 306G and 306B

is composed of photonic crystals in the same way as the color filter of the second embodiment.

When the light shielding film is provided on the light-receiving element side of the color filter 306R, 306G, and 306B in this way, it is possible to prevent light from entering light-receiving elements other than the light-receiving elements that light whose propagation direction has been changed by the color filter 306R, 306G, or 306B would normally enter. For example, in the case where there is oblique light which enters at the edge of color filter section 306G and which could, if the light shielding film 305 were not present, enter the light-receiving element 303B, the color mixing that would otherwise occur due to the oblique light can, according to the third embodiment, be prevented.

[4] Fourth Embodiment

The following describes the fourth embodiment of the present invention. The solid-state imaging device of the fourth embodiment resembles the solid-state imaging device of the second embodiment in that it is characterized by the construction of its color filter.

The color filter of the fourth embodiment is formed by a dielectric multilayer film, in which a low refractive index material, such as silicon oxide (SiO_2), and a high refractive index material, such as silicon nitride (Si_3N_4) are alternately layered. It goes without saying that the stacking direction of the layers constituting the dielectric multilayer film matches the stacking direction of the layers constituting the solid-state imaging device 2. All but one of the layers constituting the dielectric multilayer film have

substantially the same optical thickness. Here, the optical thickness of a layer is expressed as a value *nd*, which is the product of *n* denoting a refractive index of the material forming the layer, and *d* denoting the thickness of the layer.

According to this construction, the thickness of the color filter can be reduced, and consequently, the distance between the light-receiving elements and the light shielding film shortened. Consequently, according to the fourth embodiment, the prevention of color mixing caused by oblique light can made more reliable.

In order to improve collection efficiency of the micro lenses, it is necessary to increase their collection angle. However, even when this is done, the solid state-imaging device of the fourth embodiments can prevent color mixing. As a consequence, it is possible to improve sensitivity of the solid-state image device while continuing to prevent color mixing.

Industrial Applicability

The solid-state imaging device, the manufacturing method of the solid-state imaging device, and a camera using the same, which are all of the present invention, are applicable as technologies to achieve a color solid-state imaging device having a smaller size and improved performance.